Status of the POAM III Algorithm and Data Set

POAM Science Team:

R. Bevilacqua (PI,NRL)	K. Hoppel (NRL)
J. Lumpe (CPI)	M. Fromm (CPI)
C. Randall (CU)	G. Nedoluha (NRL)
D. Allen (NRL)	E. Shettle (NRL)
J. Hornstein (NRL)	A. Prados (NRL)
C. Benson (NRL)	J. Alfred (CPI)
R. Salawitch (JPL)	M. Santee (JPL)
G. Manney (JPL)	D. Rusch (CU)
A. Strawa (NARC)	K. Drdla (NARC)
C. Brogniez (Lille)	H. Steele (CSUN)
B. Connor (NIWA)	K. Kreher (NIWA)
S. Massie (NCAR)	L. Pan (NCAR)

Solar Occultation Satellite Science Team Meeting
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R. Bevilacqua

Polar Ozone and Aerosol Measurement (POAM) Program

POAM is a 9-channel visible/near infrared photometer for making measurements of stratospheric constituents using solar occultation techniques.

POAM III
Designed, Fabricated, & Qualified by
TREX ≡ ENTERPRISES
San Diego, California

- **POAM II was launched on 26 Sep., 1993 on the French SPOT 3 spacecraft into a polar sun synchronous orbit (98.7° inclination, 10:30 equatorial crossing) and operated until the satellite failed in Nov. 1996.**

- **The POAM II measurement complement includes:**
  Ozone (10-60 km)
  Aerosol Extinction (10-30)
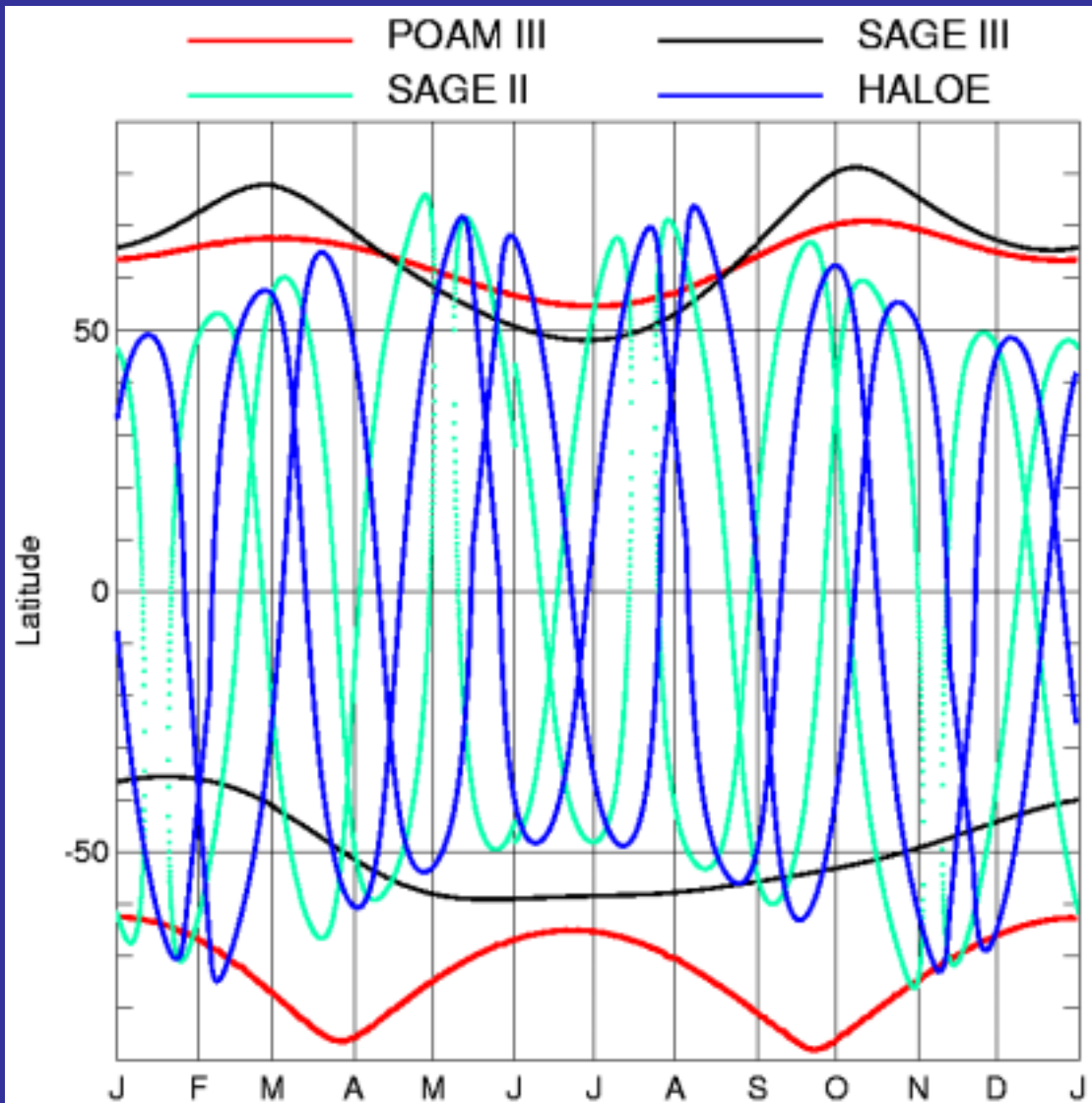 **Nitrogen Dioxide (20-40 km)**

- **POAM III was launched on SPOT 4 (orbit identical to that of POAM II) on 23 March 1998. The instrument is currently operational.**

- **The POAM III measurements:**
  Ozone (5-60 km)
  Aerosol Extinction (5-30 km)
  Nitrogen Dioxide (20-45 km)
  Water Vapor (5-45 km)
  Atmospheric Density (30-60 km)

Polar Ozone and Aerosol Measurement (POAM) Program

- **POAM II and III measurement coverage is identical, and are both annually periodic.**

- **The POAM measurements provide continuous coverage of the polar regions.**

- **POAM is complementary to SAGE III, which measures to higher latitudes in the north, but lower latitudes in the south.**

- **The POAM measurement coverage is nearly identical to that of ILAS I and II**

POAM Measurement Channels

Channel	Center wavelength (nm)		Bandwidth (nm)		Primary Purpose	
	POAM II	POAM III	POAM II	POAM III	POAM II	POAM III
1	352	354	4.5	10	Rayleigh	Rayleigh
2	442	440	2	2	NO_2 off/Aer	NO_2 on
3	448	442	2	2	NO_2 on	NO_2 off/Aer
4	601	603	14	18	O_3	O_3
5	761	761	2	2	O_2 on	O_2 on
6	781	779	17	10	O_2 off / Aer	O_2 off/Aer
7	921	922	2	2.5	H_2O off/Aer	H_2O off/Aer
8	936	936	2	2.5	H_2O on	H_2O on
9	1060	1018	11	12	Aerosol	Aerosol

POAM III Version 3 algorithm (current operational algorithm)

❑ **Retrievals done on a 1-km altitude grid**

❑ **Three step approach:**

1. **Computation of total slant optical depths**

2. **Spectral inversion:**
   - ➤ **Simultaneous retrieval of O_3, O_2, NO_2, H_2O, and aerosol slant path column densities at each altitude grid point.**
   - ➤ **Assume the following parameterization for the λ dependence of the aerosol optical depth:**

$$\ln \delta_{aer}(\lambda) = \mu_o + \mu_1 \ln \lambda + \mu_2 \ln^2 \lambda$$

3. **Limb inversion:**
   - ➤ **Converts slant path column densities and aerosol optical depths to gas concentration and aerosol extinction profiles.**

Retrieval Error Analysis

Comparison of Calculated Errors to Retrieval Precision
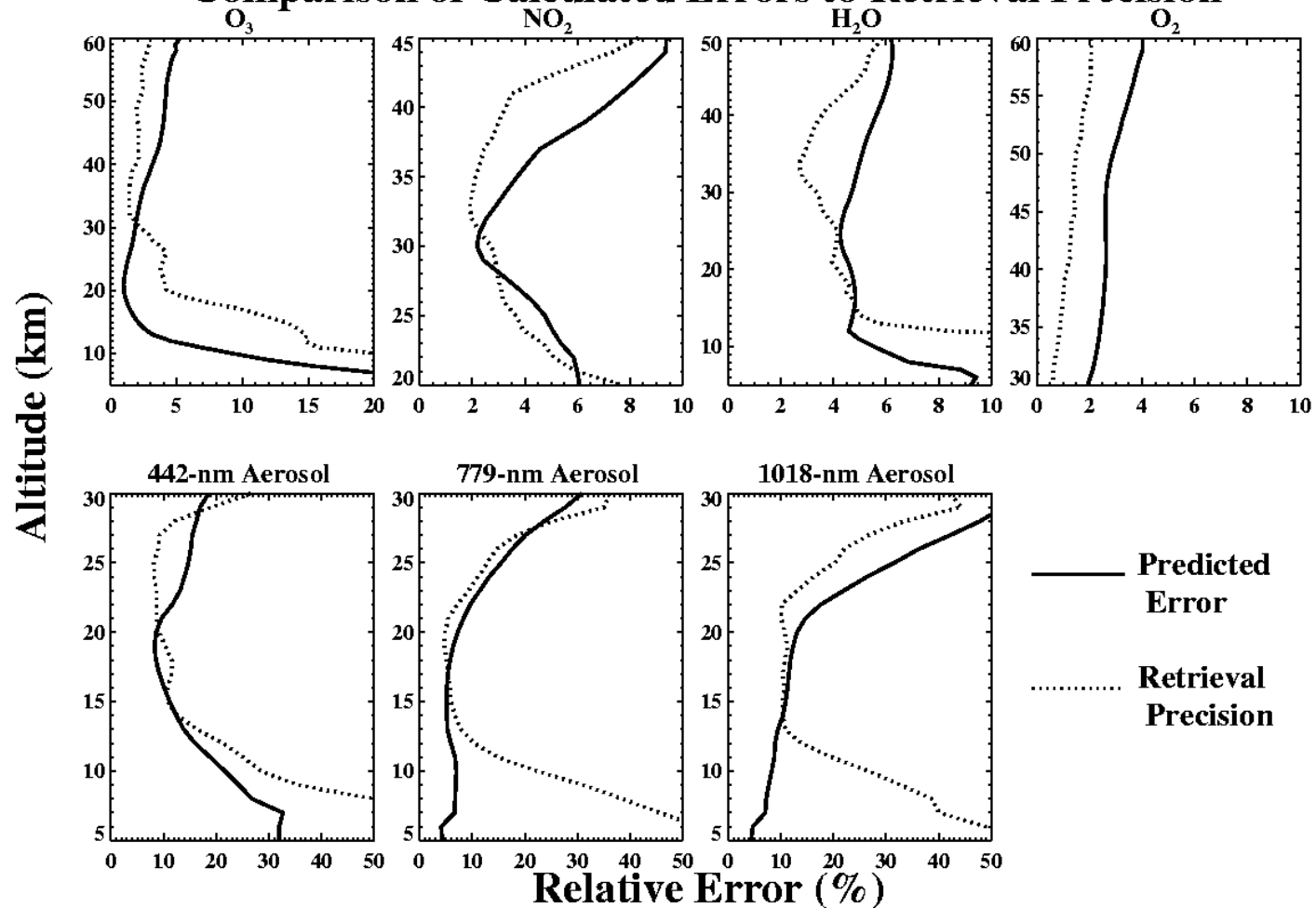
Retrieval Vertical Resolution
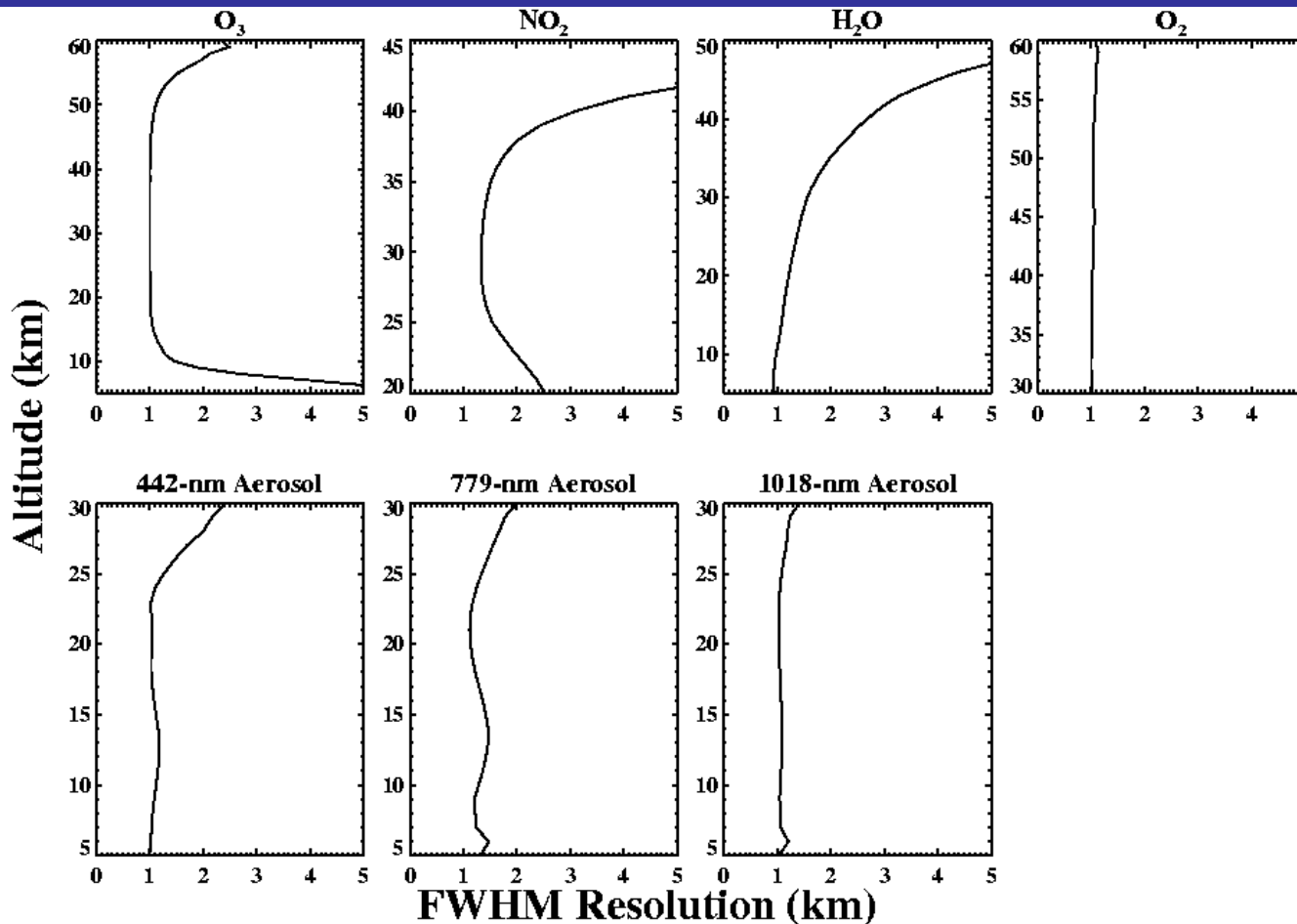
Over most of the retrieval range, the POAM constituent retrieval vertical resolution is ~ 1-2 km. Degradation in resolution at the highest and lowest altitudes is the result of decreasing SNR

Sunspot Artifact Errors
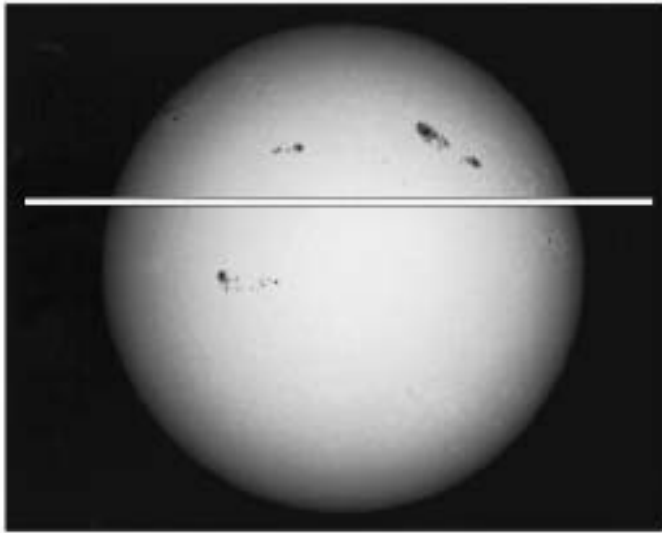
❑ **Sunspots can cause a decrease in signal well above the noise level.**

❑ **Because the sun is scanned above the atmosphere in each event, with accurate determination of the tracking offset, the sunspot effect will be normalized out.**

❑ **The effect of small, random pointing errors is magnified by sunspots.**

Typical Sunspot in a POAM Sun Scan (Index = 10)
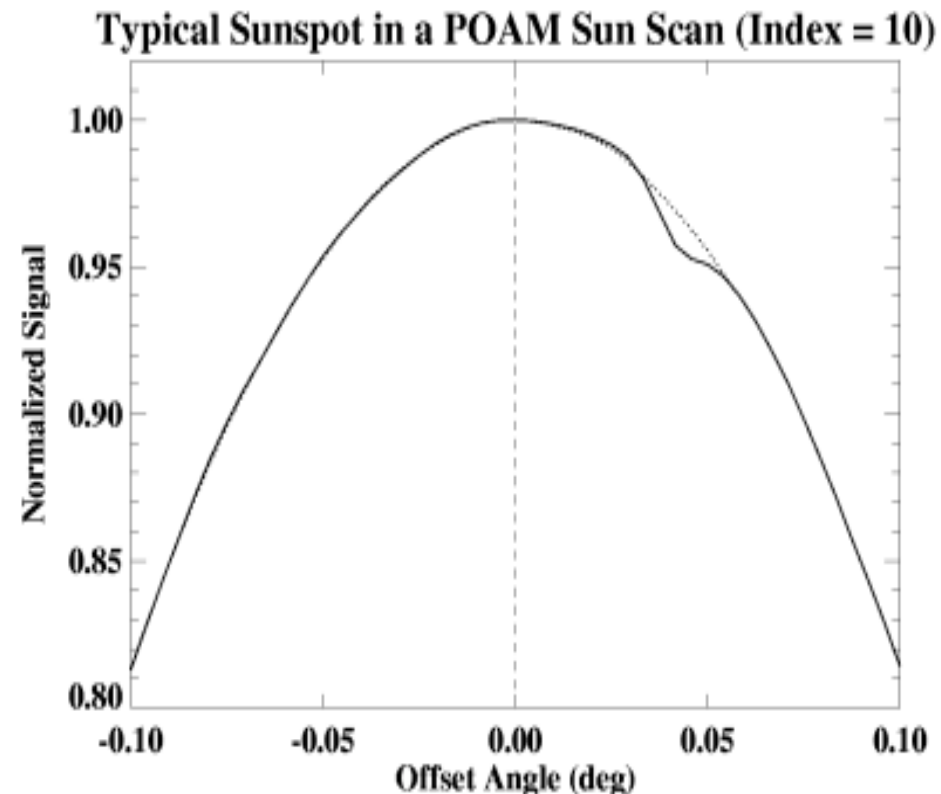
Polar Ozone and Aerosol Measurement (POAM) Program

Empirical error bars due to sunspot artifacts.
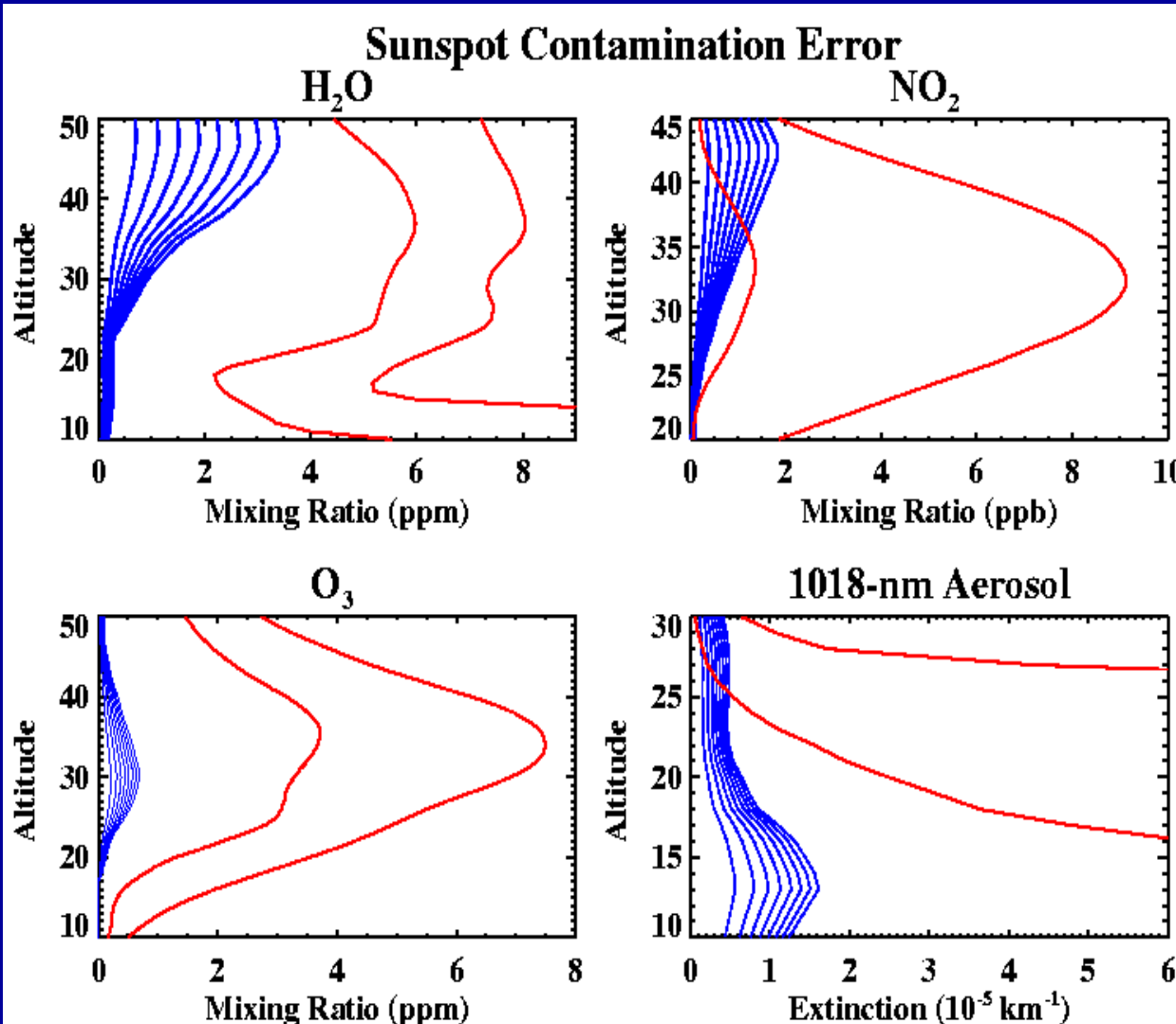
•Errors for sunspot indices of 1-8

• Range of profiles

Empirical error bars due to sunspot artifacts.
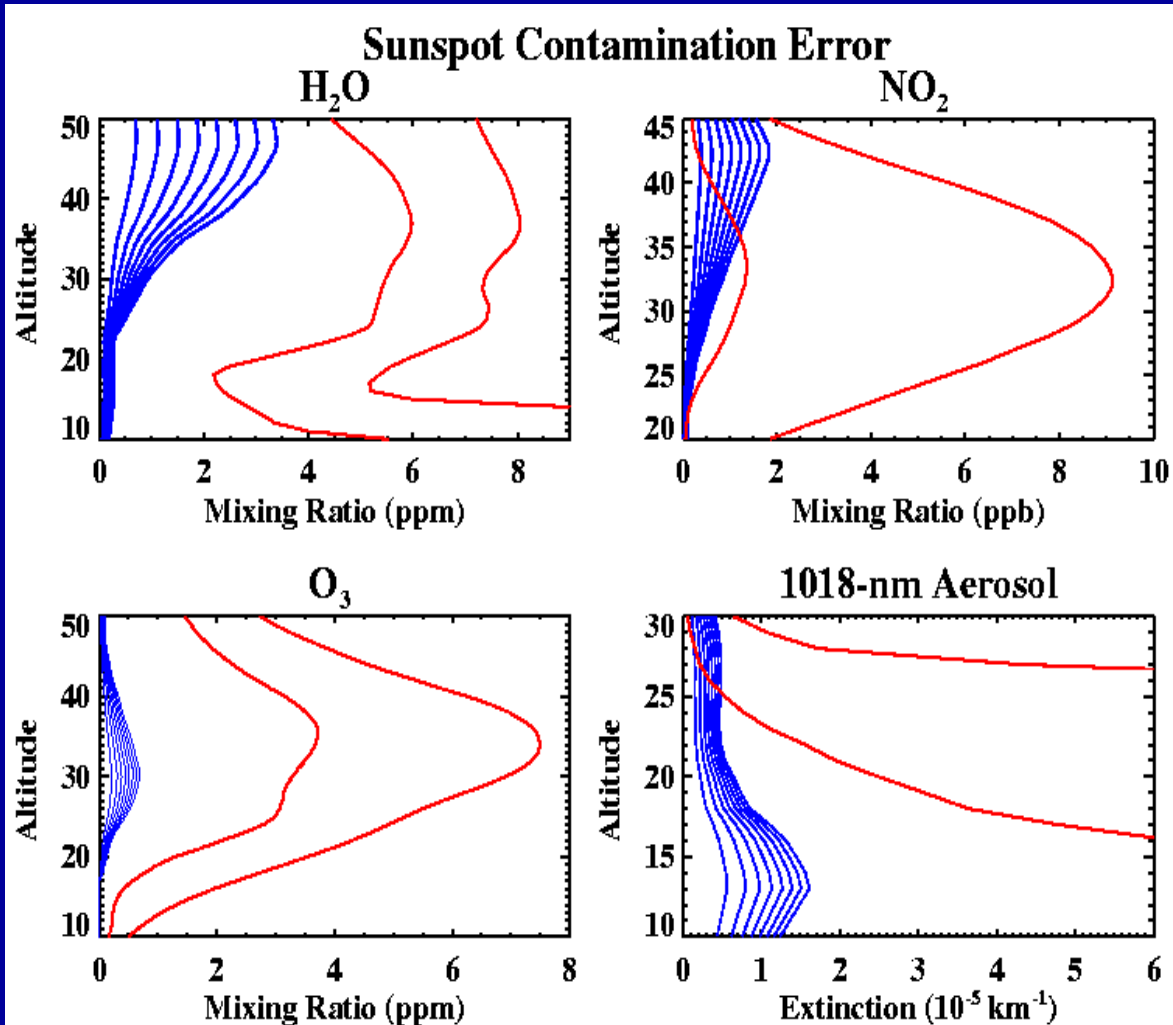
- NO$_2$ & H$_2$O are most affected.
- O$_3$ & aerosols nearly unaffected.
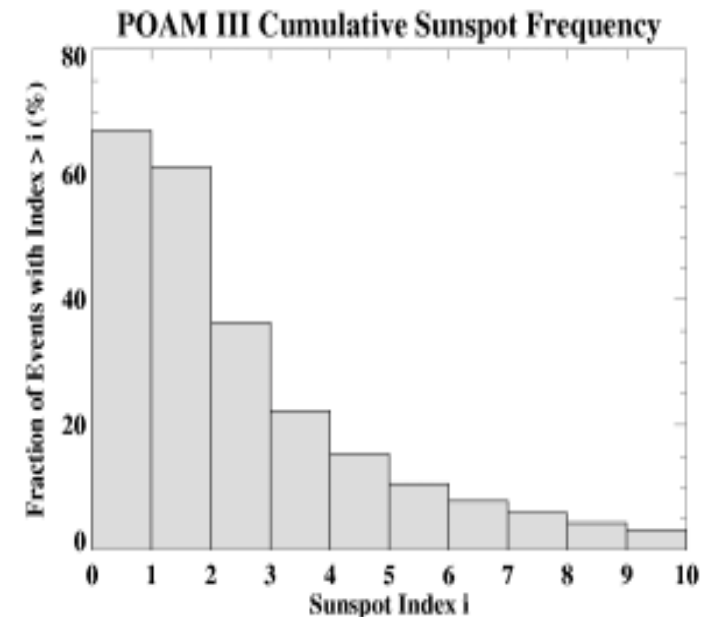
Aerosol Contamination Error
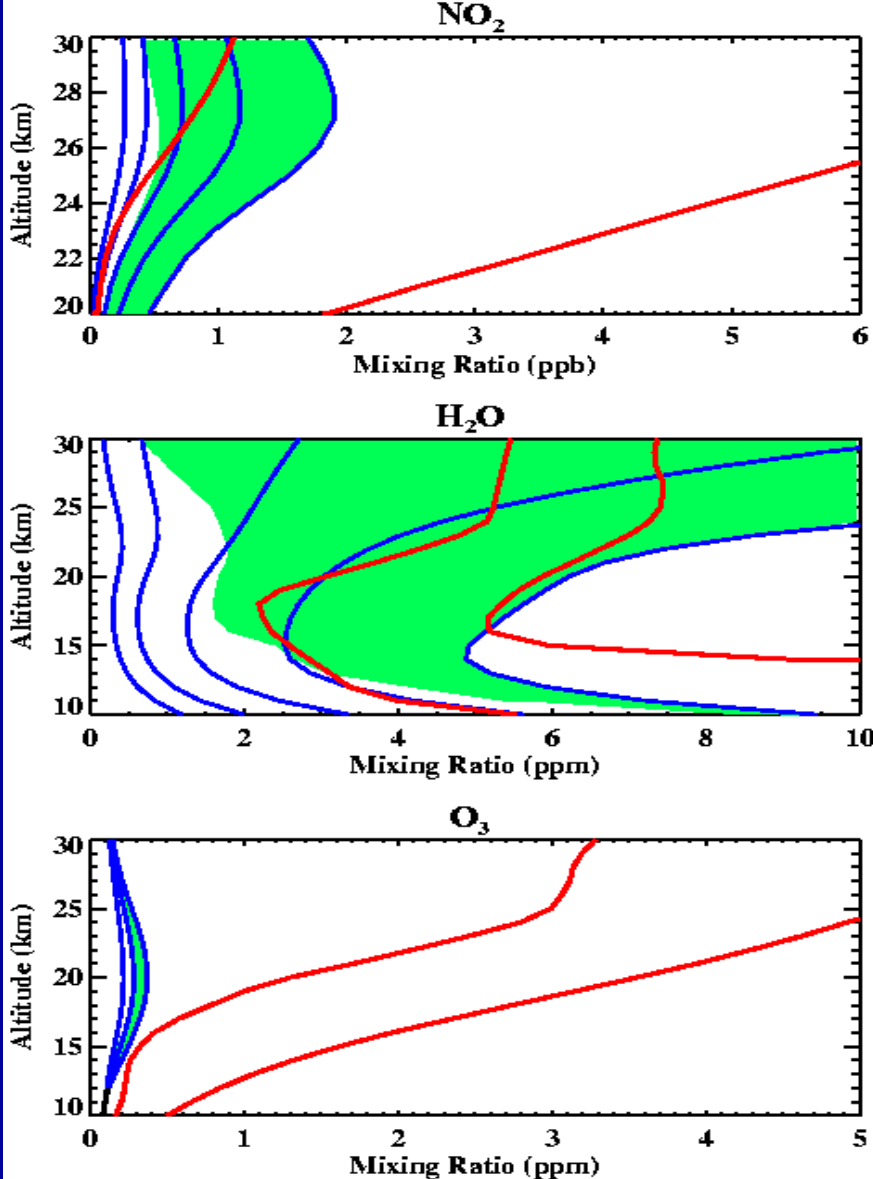
Empirical Errors due to Aerosol Contamination

- Errors for aerosol extinction of $10^{-6} - 10^{-2}$ km^{-1}
- Range of retrieved values
- PSC extinction range

- NO_2 and H_2O can be impacted by high aerosol loading typical of PSCs.

- O_3 impact is minimal.

POAM Validation Summary

- **Ozone**
  Lumpe *et al.*, in press at JGR, 2002.
  Prados *et al.*, in press at JGR, 2002.
  Randall *et al.*, in press at JGR, 2003.

- **Aerosols**
  Randall *et al.*, *JGR* 106, 27525-27536, 2001.

- **NO_2**
  Randall *et al.*, JGR 107, 2001JD001520, 2002.

- **H_2O**
  Nedoluha *et al.*, *JGR*, 107, 2001JD001184, 2002.
  Bevilacqua *et al.*, in preparation.

Ozone Validation: Satellite and Sonde Comparisons

From Randall *et al*., in press *JGR*, 2003
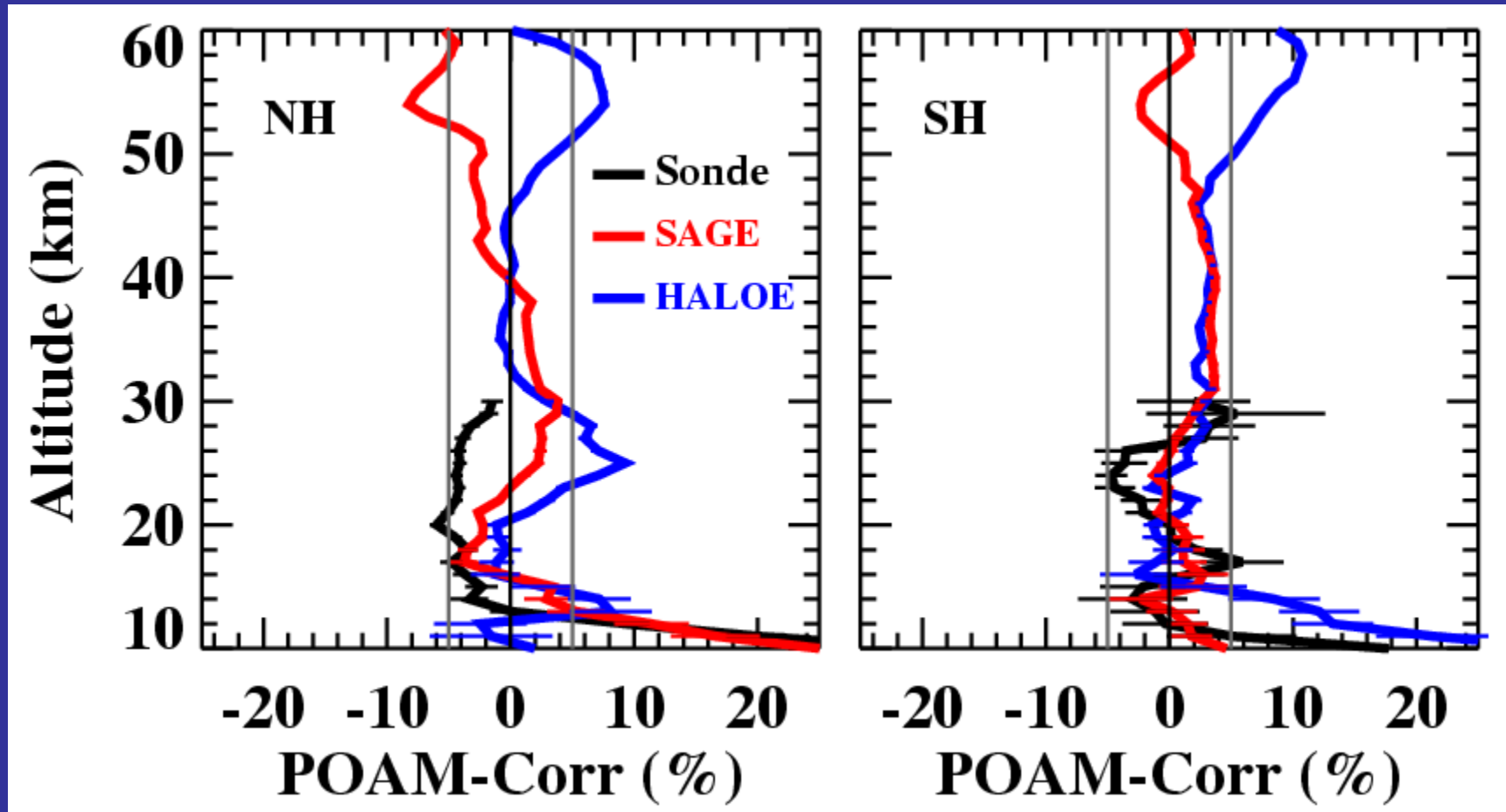
Ozone Validation: MOZAIC Comparisons

POAM/MOZAIC Coincidences

From Prados *et al.*, in press at *JGR*, 2002
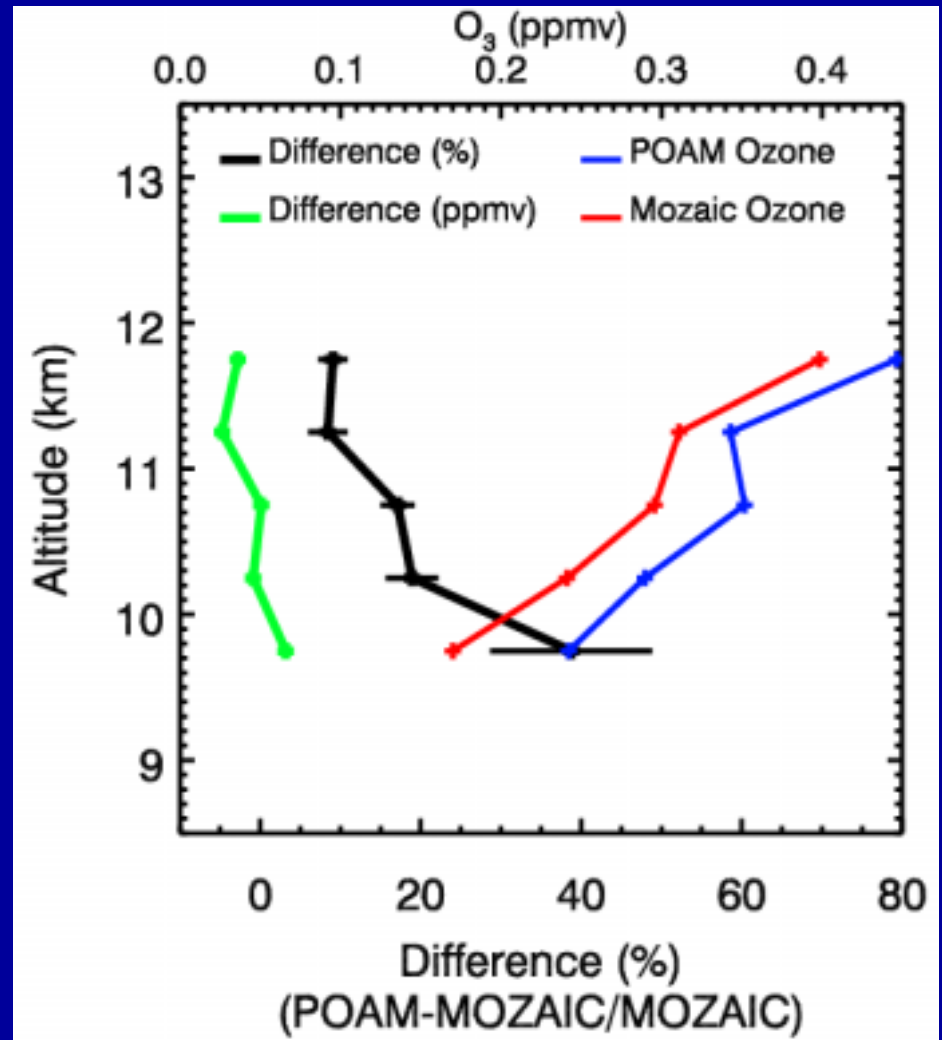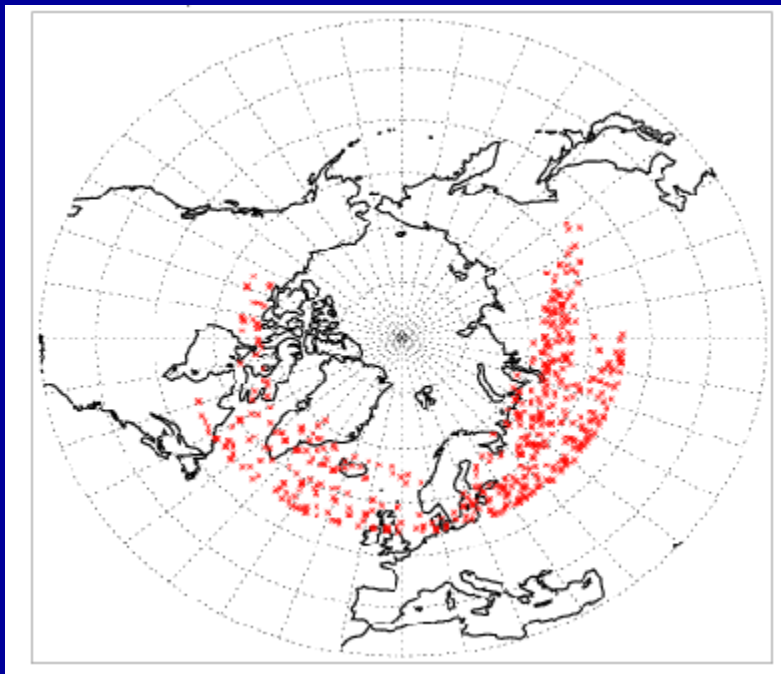
Aerosol Validation: SAGE II Extinction Comparisons
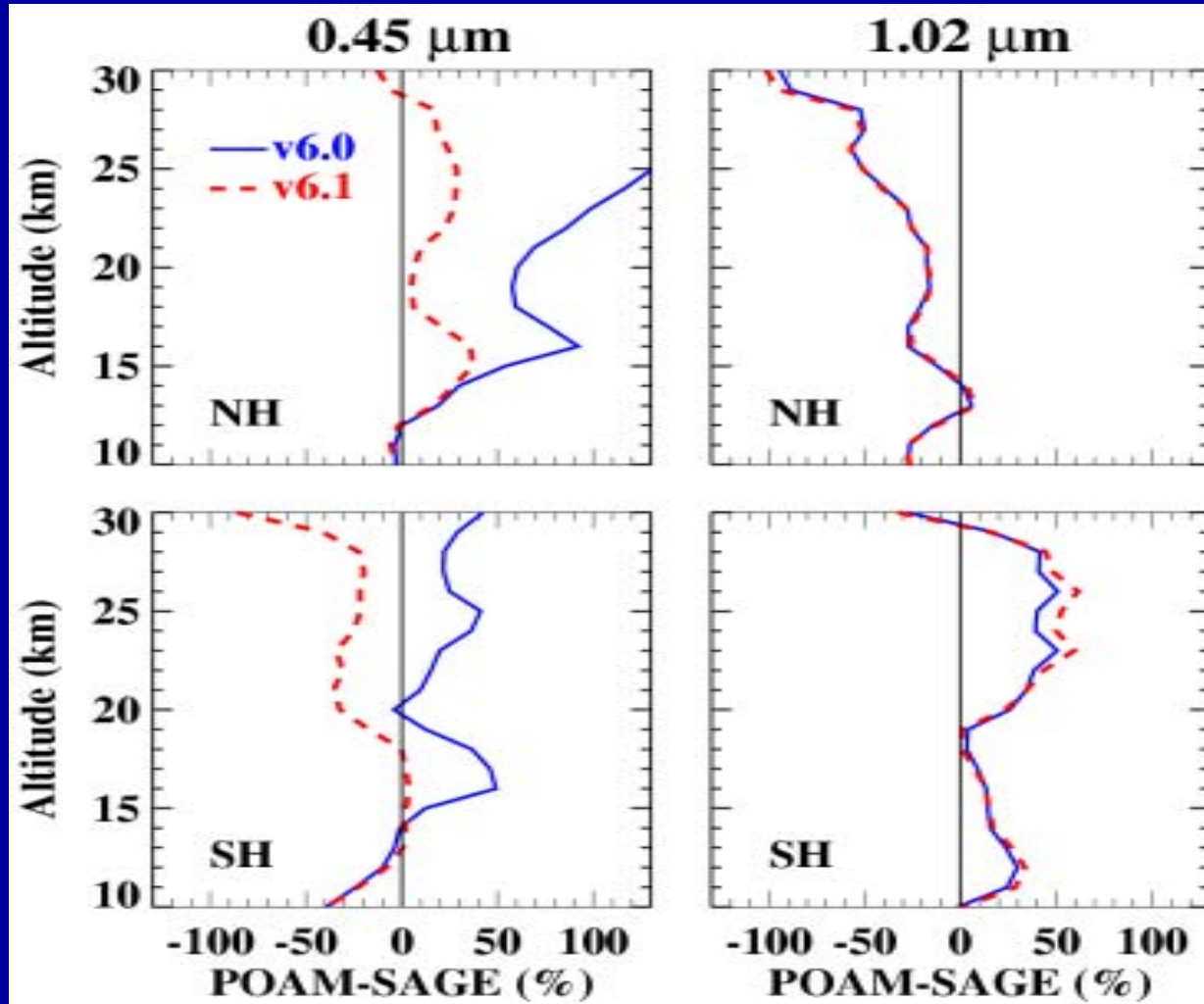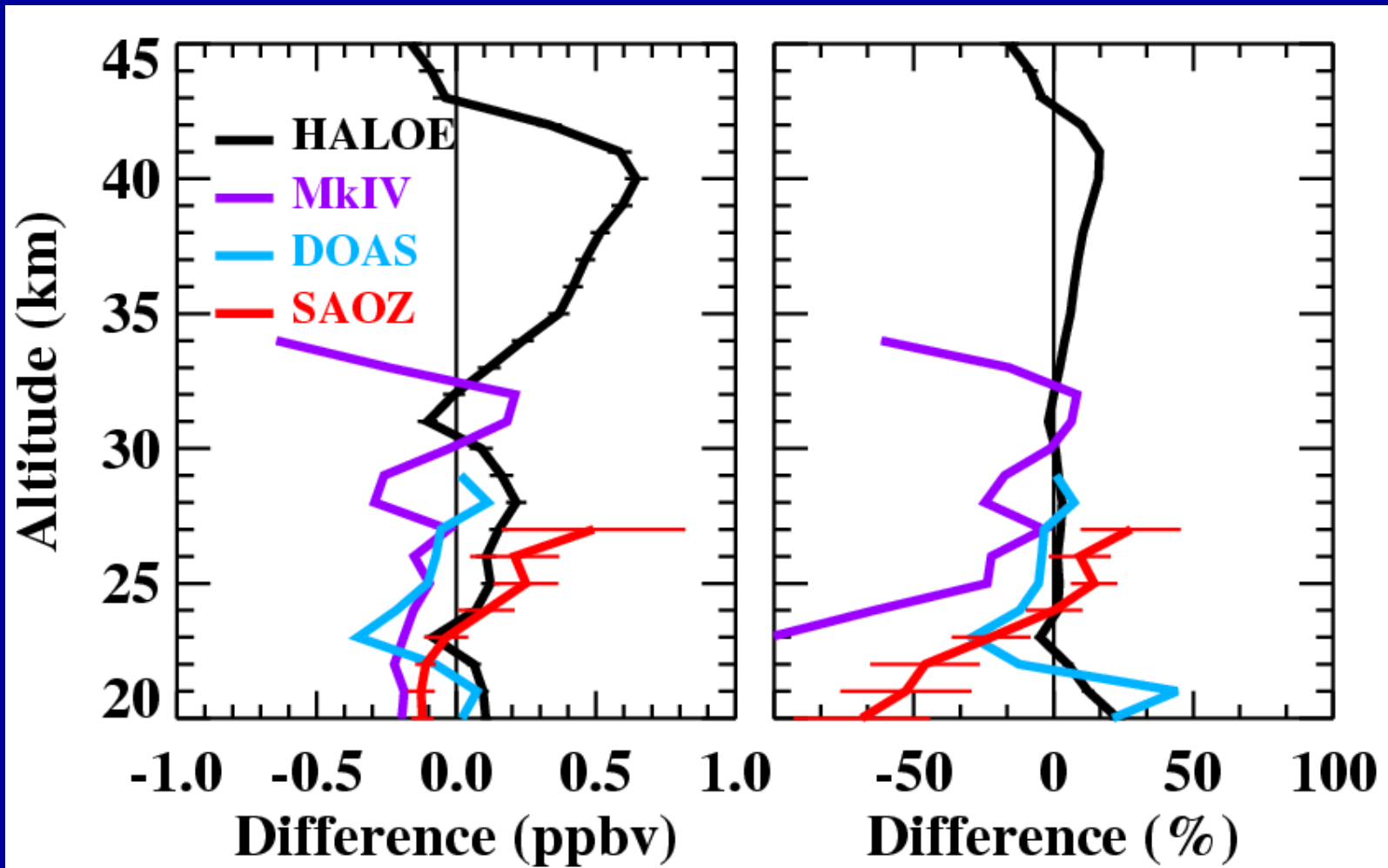
NO$_2$ Validation: HALOE and SOLVE Comparisons
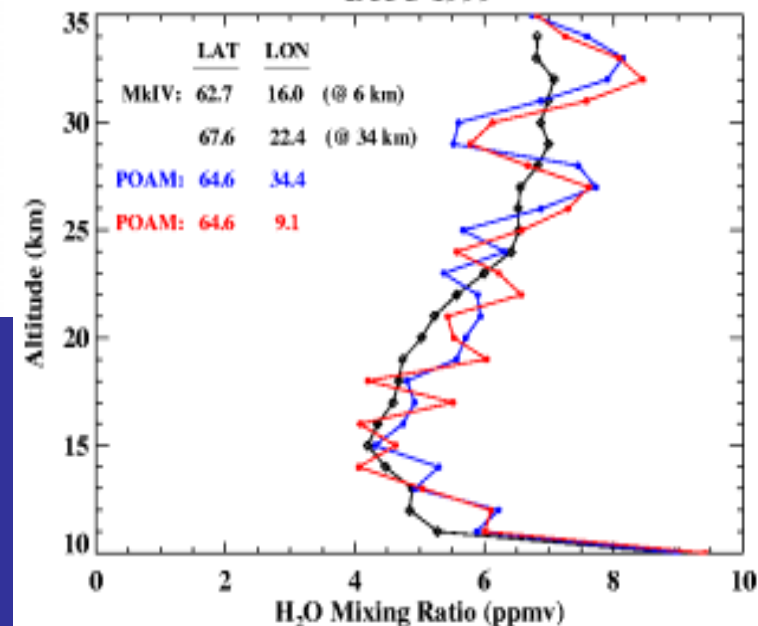
H₂O Validation: HALOE and SOLVE Comparisons
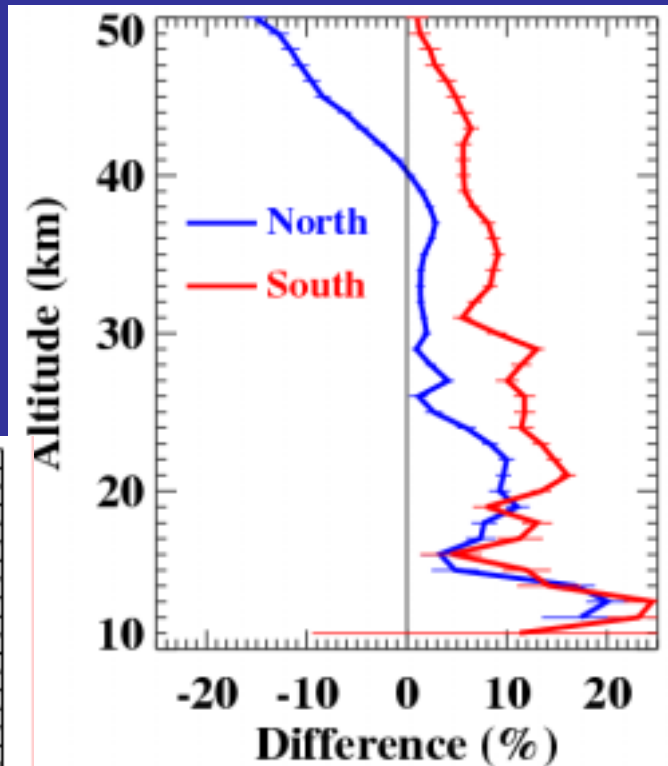
POAM/ HALOE Summary
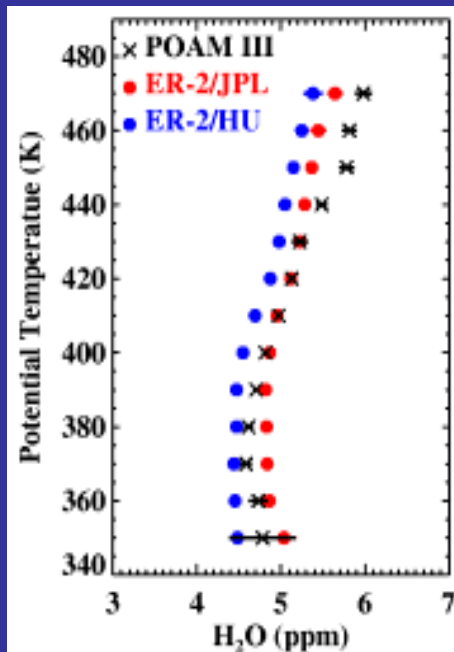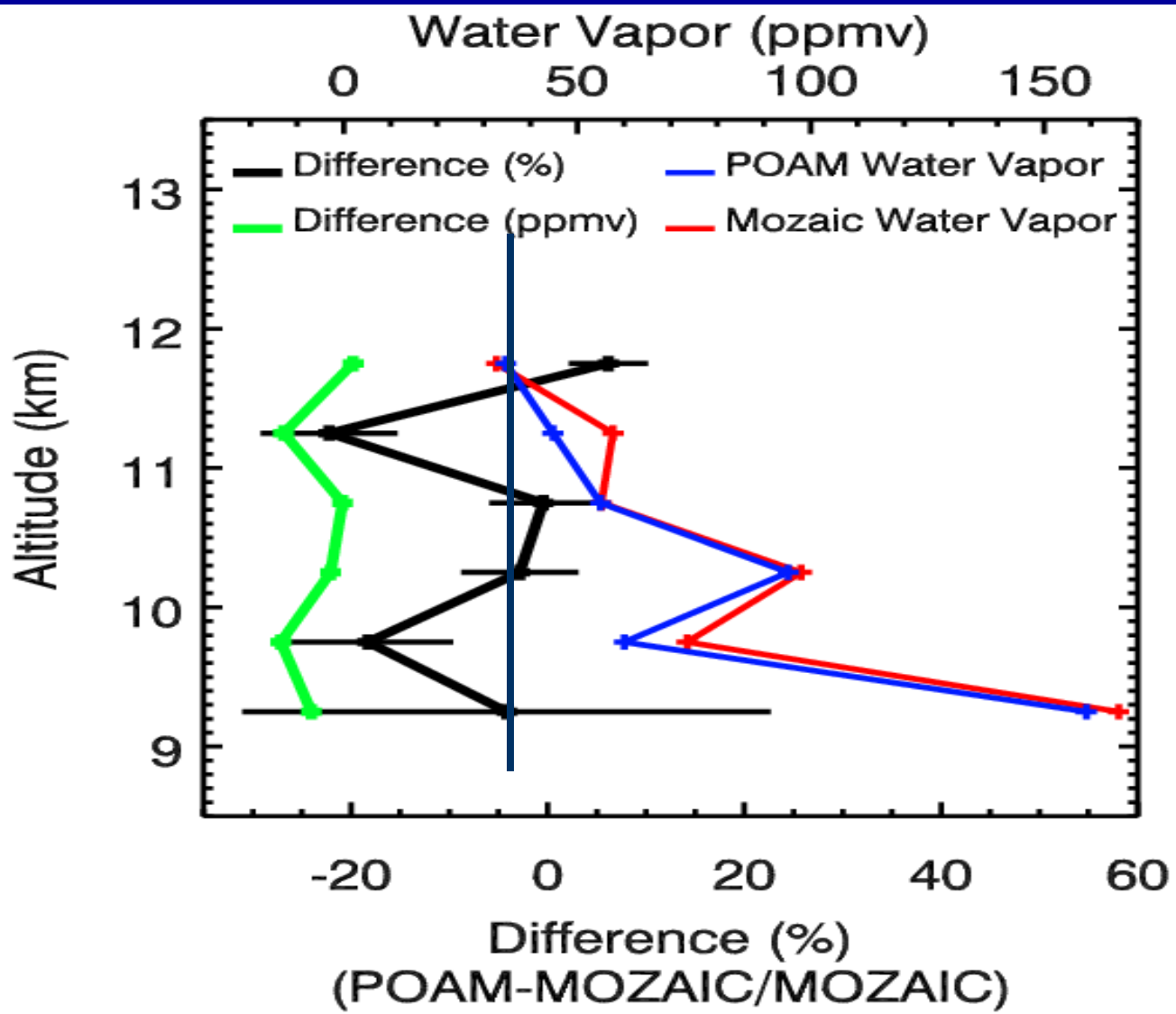
SOLVE-1 Comparisons

Bevilacqua et al., in prep., 2002

Comparison of POAM III and MkIV H₂O Profiles Dec 3 1999

H₂O Validation: MOZAIC Comparisons

POAM temperature retrieval

❑ Uses O_2 densities retrieved from Rayleigh scattering (not O_2 A band)

❑ Not operational in Ver. 3

POAM/HALOE & POAM/UKMO Temperature Comparison Study

POAM-HALOE
POAM-UKMO
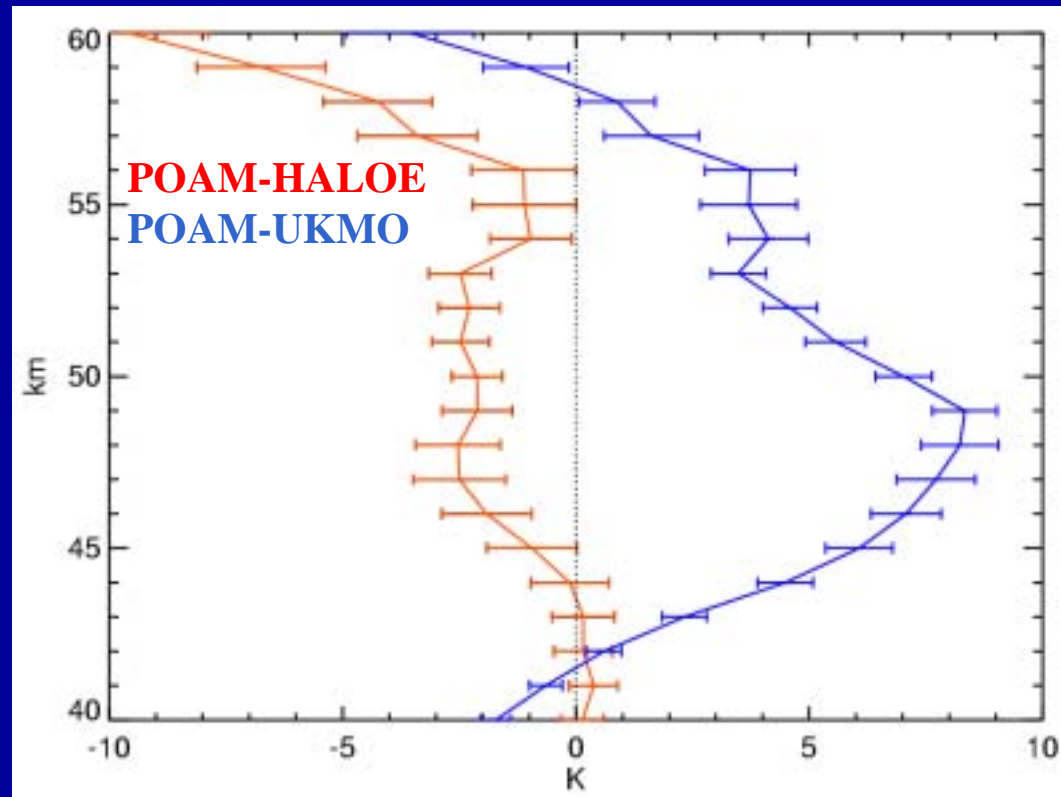
POAM III Validation Summary

Ozone

Range:	**5-60 km**
Resolution:	**1 km**
Random Error:	**5%**
SR/SS Bias:	**SS > SR, 5%**
	(30-60 km)
Validation:	**±5%, Z > 12 km**

H_2O

Range:	**5-50 km**
Resolution:	**1-3 km**
Random Error:	**5%**
SR/SS Bias:	**SS > SR, 5%**
	(20-50 km)
Validation:	**5% high bias**

NO_2

Range:	**20-45 km**
Resolution:	**1.5-3 km**
Random Error:	**5%**
SR/SS Bias:	**Insignificant**
Validation:	**±5-10%**
	Diurnal correction

Aerosols

Range:	**5-30 km**
Resolution:	**1 km**
Random Error:	**10-20%**
SR/SS Bias:	**SR < SS**
	SR > SS
Validation:	**±30%, background**

Sunspots
$H_2O > NO_2 > O_3$

Aerosols
$H_2O > NO_2 > O_3$

On to Version 4: Objectives

- **Improved pointing information in transmission algorithms.**

- **New aerosol parameterization in spectral inversion.**

- **Investigate modifying the constraints in the retrieval.**

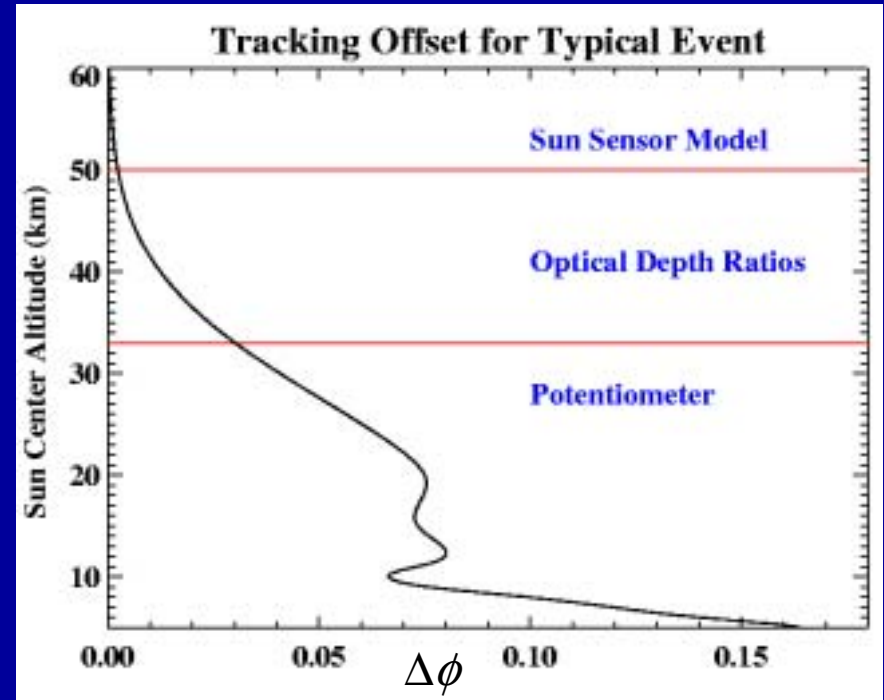- **Operational temperature retrieval.**

- **Incorporation of oxygen A band (?).**

POAM pointing issues:

- **POAM FOV is wider than the width of the sun**
- **POAM tracks on the sun center of brightness.**
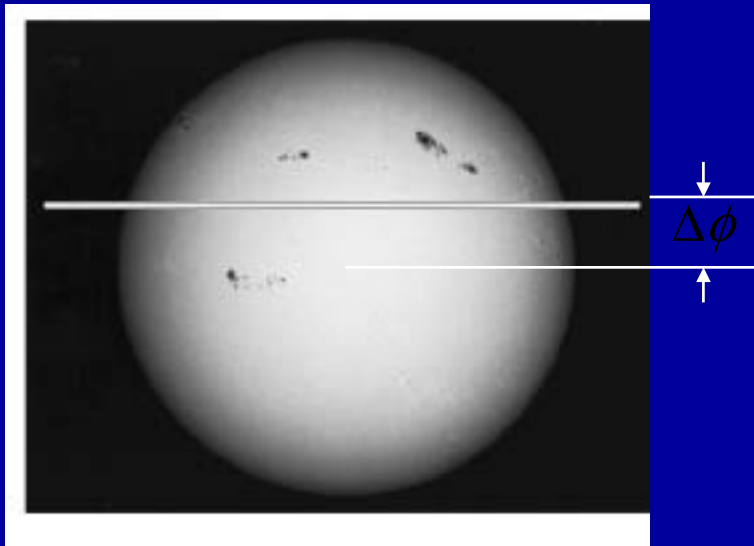
Instrument tracking on the solar disk.

Altitude regimes currently used in Ver. 3 algorithm

Aerosol Parameterization

Version 3 nonlinear parameterization:

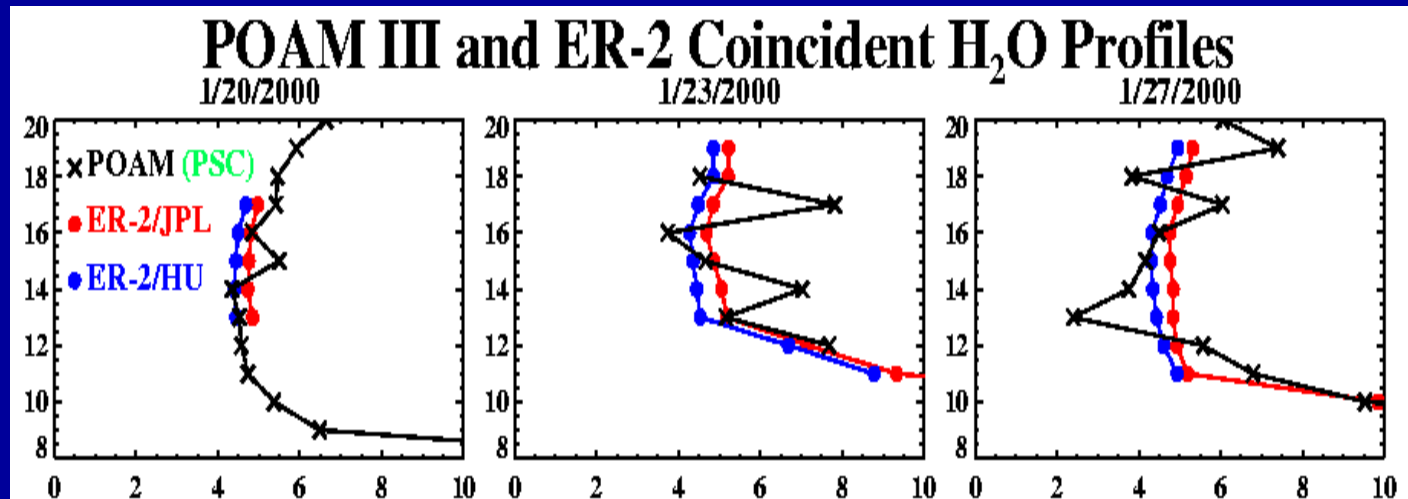$$\ln \delta_{aer}(\lambda) = \mu_o + \mu_1 \ln \lambda + \mu_2 \ln^2 \lambda$$

Possible alternate linear parameterizations:

$$\delta_{aer}(\lambda) = \mu_o + \mu_1 \ln(\lambda/\lambda_9) + \mu_2 \ln^2(\lambda/\lambda_9)$$

$$= \mu_o + \mu_1 \lambda^{-1} + \mu_2 \lambda^{-4}$$
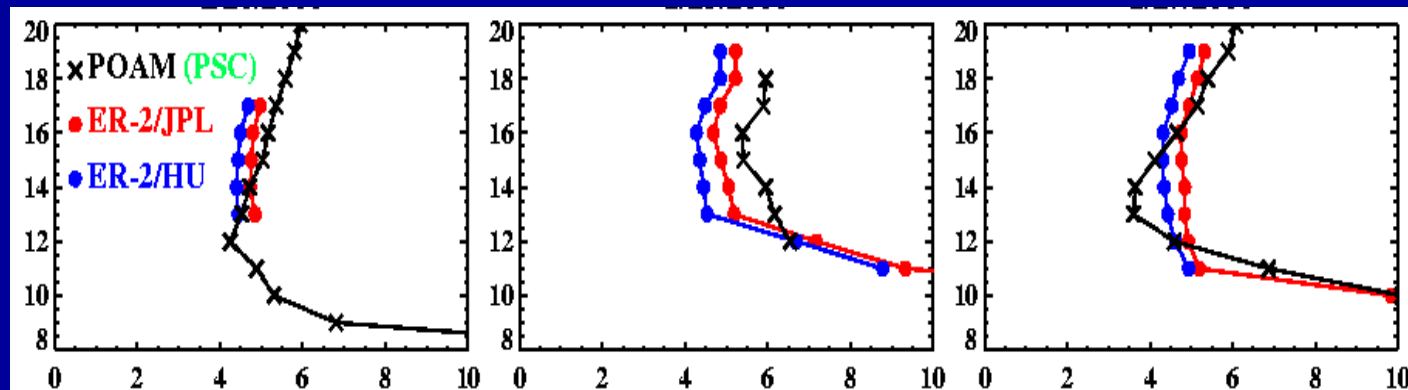
$$= \sum_i \mu_i T_i(\lambda)$$

Example of effect of tighter constraints on H_2O retrievals during SOLVE.

Version 3

Test Version (tightened constraints)

Science Highlights

■ **Polar Stratospheric Clouds**
  ▸ **Unique PSC data set in the 1990's**

■ **Ozone Depletion**
  ▸ **Contributed to NASA SOLVE I and II missions**
  ▸ **Measures Arctic ozone variations.**
  ▸ **Formation and evolution of Antarctic ozone hole.**
  ▸ **Dehydration of the Antarctic vortex.**

■ **Upper Troposphere/Lower Stratosphere**
  ▸ **First evidence that boreal forest fire smoke can reach the lower stratosphere.**
  ▸ **Diagnostic of UT/LS transport via water vapor and ozone morphology.**

■ **Mesosphere/Stratosphere Coupling**
  ▸ **Detected stratospheric ozone loss after transport of enhanced odd nitrogen across the stratopause.**
  ▸ **First satellite measurements of PMCs in extinction -- possible climate change implications.**
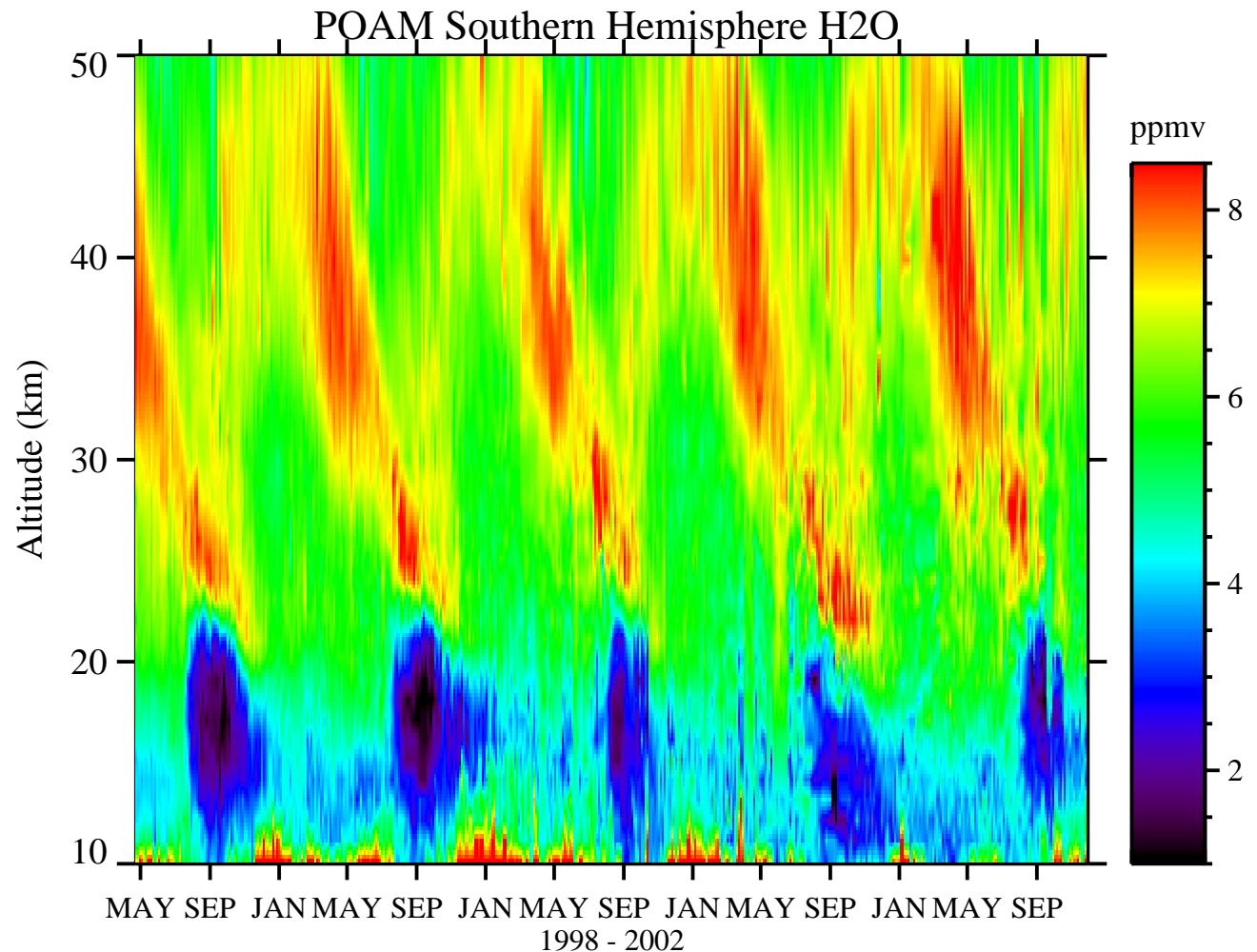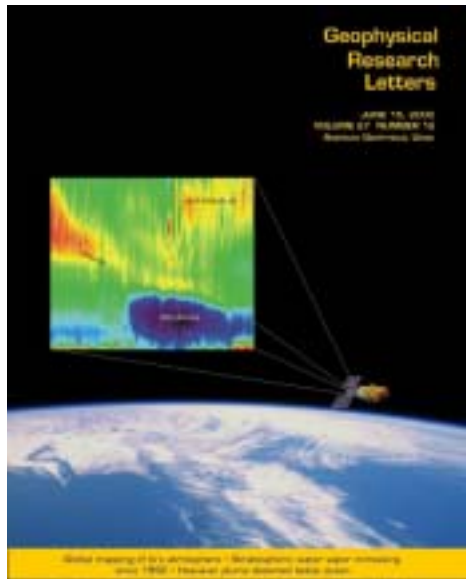
Important science issues which can be addressed by solar occultation measurements :

❑ **Ozone Loss**

❑ **PSC microphysics: Strawa et al. (2003) PSC type discrimination algorithm**

❑ **Dehydration of the Antarctic polar stratosphere**

❑ **UT/LS issues**

Dehydration of the Antarctic Vortex

POAM Southern Hemisphere H2O

Dehydration of the Antarctic Vortex

500K
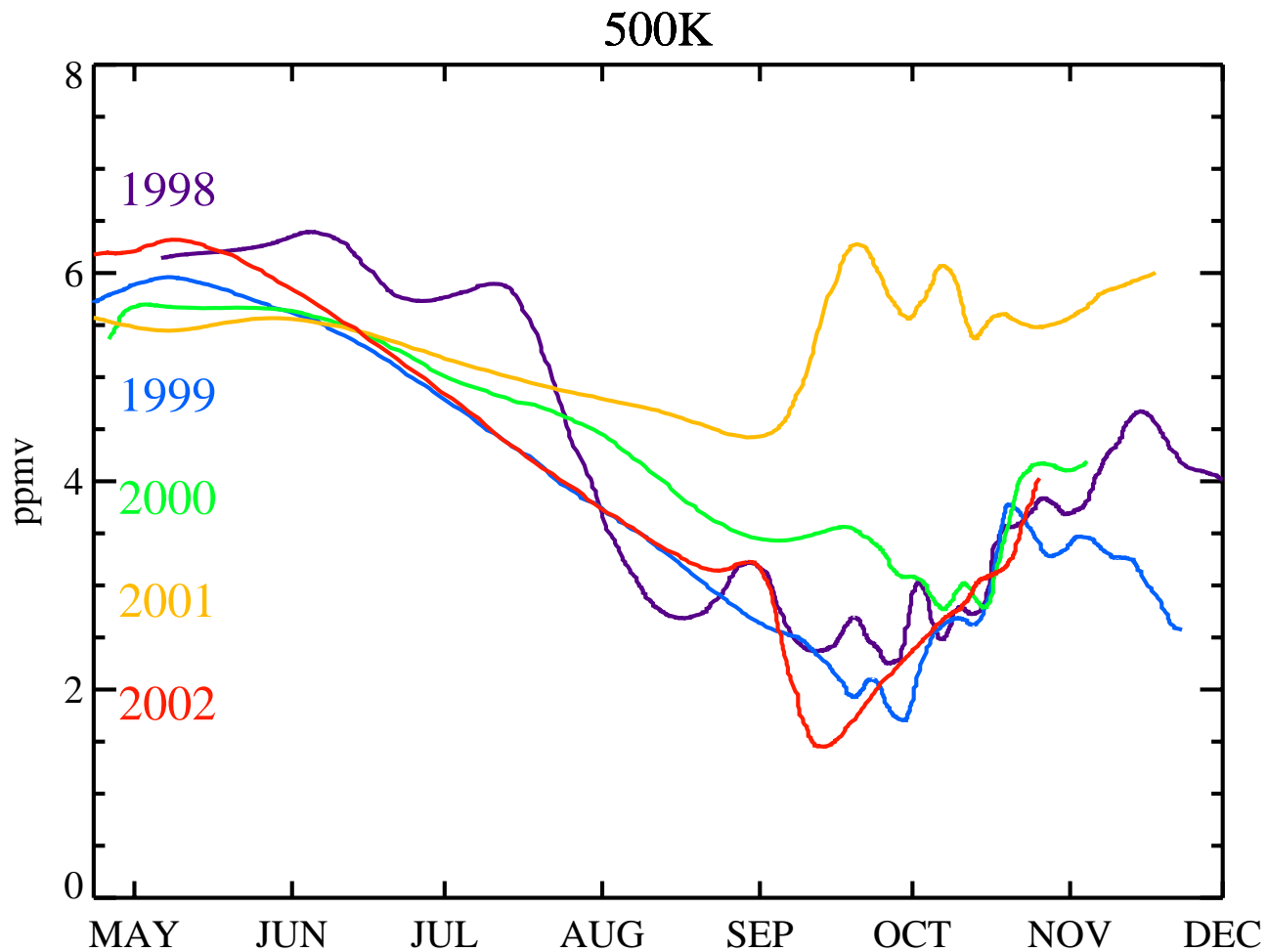
Dehydration of the Antarctic Vortex: measurement/model

Water Vapor Mixing Ratio, 500 K
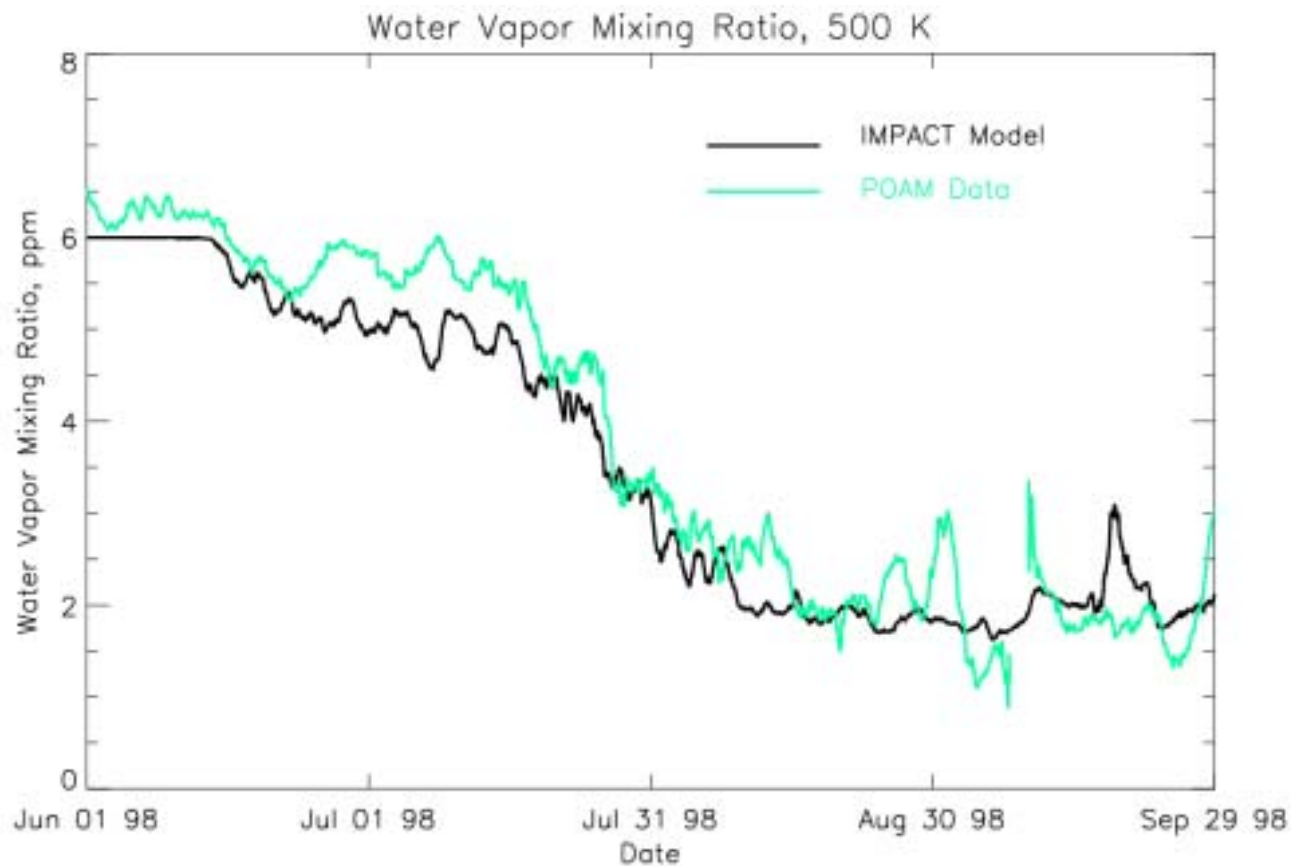
POAM ozone and water vapor in the UT/LS

POAM/MOZAIC comparisons
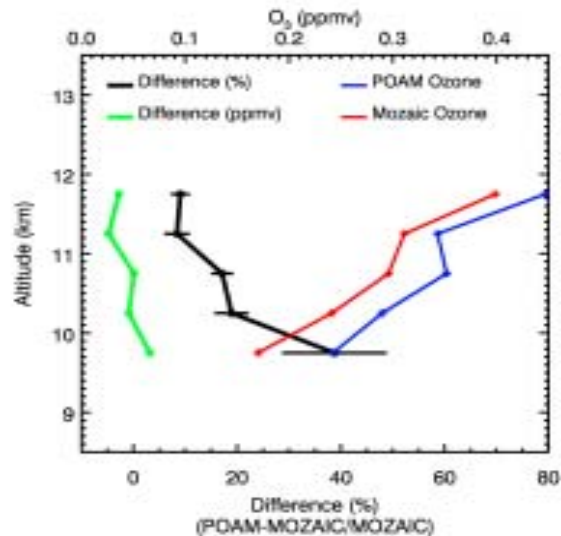
Prados et al., 2003
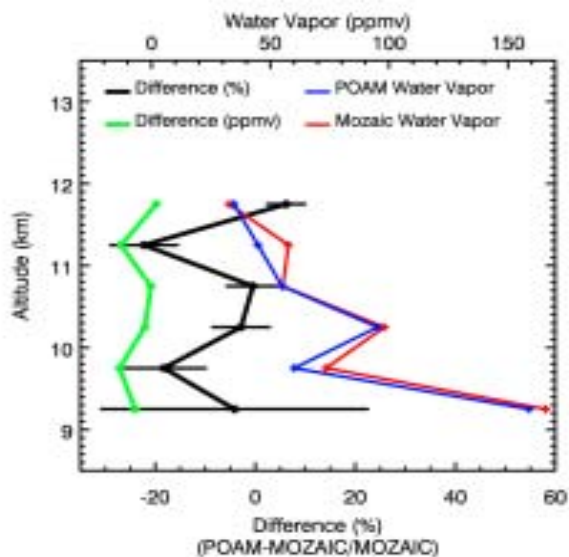
Nedoluha et al., 2002
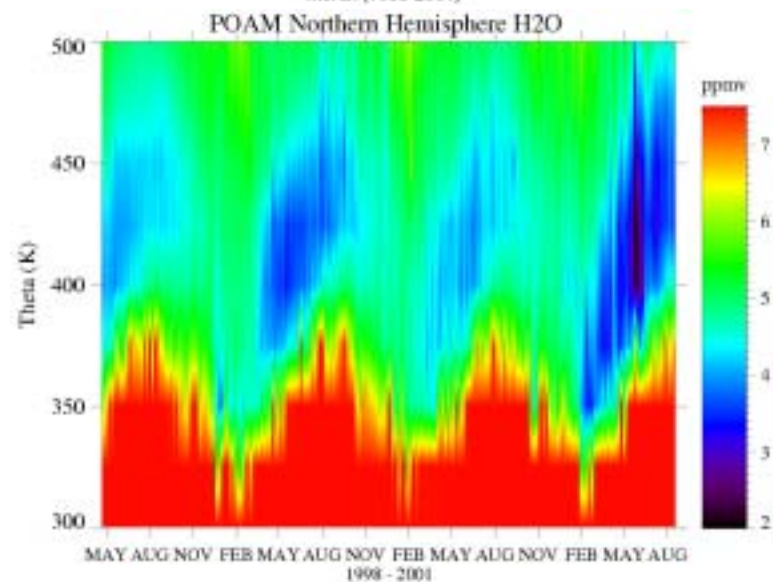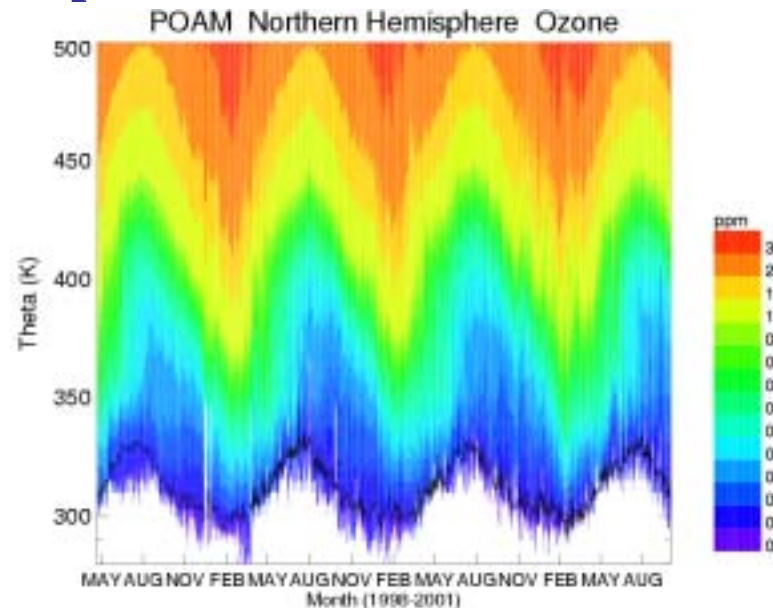
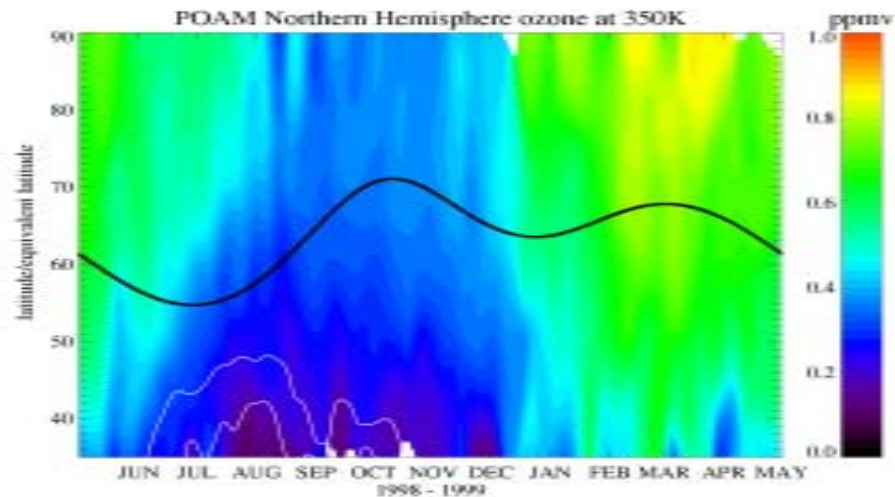## POAM ozone and water vapor in the UT/LS

Troposphere to Stratosphere Exchange
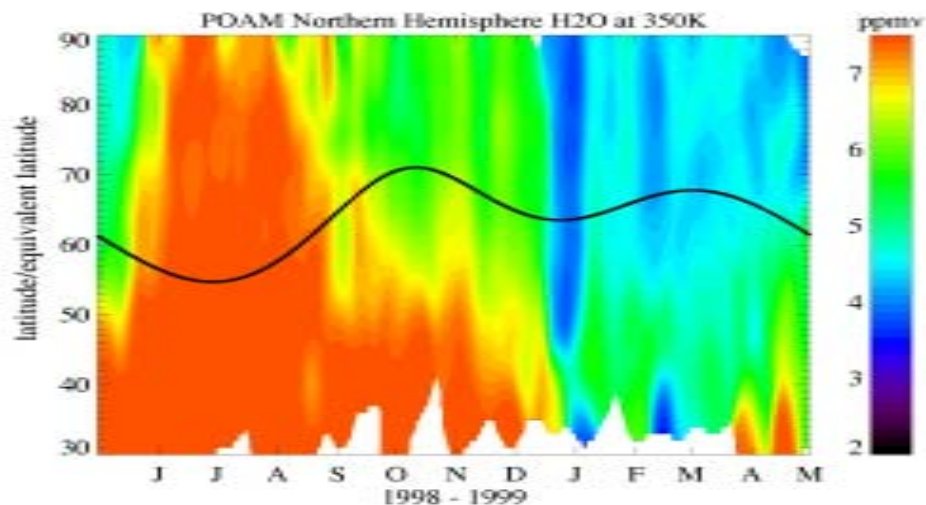
Summary:

❑ **POAM III was launched in March 1998, and is currently operational. It is the successor to POAM II which operated from Oct. 1993 to Nov. 1996.**

❑ **The current retrieval version is Ver. 3, which has now been validated.**

❑ **POAM II data is archived at the Langley DAAC,   and POAM III data is publicly available (http://wvms.nrl.navy.mil/POAM/ and http://www.cpi.com/products/poam)**

❑ **POAM validation and science publication record to date (since 1995):**

  Refereed journals: 60 publications, 5 in press, and 1 submitted.
  Papers in conference proceedings: 20
  Presentations: more than 150.